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Development and evaluation of a device to incorporate biodegradable textiles into sports turfs

Bastian Stürmer-Stephan, Jörg Morhard, Hans W. Griepentrog

In Germany, approximately 55,000 soccer pitches are in use regularly. Sport pitches should have a period of use of about 800 h/year regardless of weather conditions. The sandy root zones of the pitches generally need artificial irrigation. This results in excessive water use during drought. The incorporation of a biodegradable textile, further named nonwoven is intended to improve the water availability for the turf cover and elongate the period of usage of standard sport pitches. The present study aims to develop and evaluate a device for the vertical incorporation of a nonwoven 150 mm in height into existing pitches at a maximum depth of 170 mm. The device cuts the turfgrass, opens a slit with a box coulter and incorporates a nonwoven into the root zone layer. An attached pressure roller then recompacts the disturbed surface area. A field trial was conducted to evaluate the device's variation in working depth and recompaction efficiency, as well as to assess the damage to the turf cover. The variation of the working depth was less than 20 mm. The soil recompaction, measured as penetration resistance, was similar to the status quo, except in the area close to the nonwoven, where the recompaction failed. The turf damage was less than 15 % of the ground cover, which meets the playability requirements. While the device worked within its specifications, further research needs to be conducted in order to investigate the benefits of nonwovens with regards to water use, the impact on the turf cover and its wear.

Keywords
lawn, water, device, nonwoven, turf, sport, pitch

Soccer, one of the most common sports worldwide, is performed on turf surfaces specially designed for this purpose. Since these surfaces are in use during all seasons, they must remain playable during most weather conditions. Turfgrass for this purpose normally grows on an artificial layer-by-layer system. Evapotranspiration from the vegetation layer as well as local weather conditions should be considered with regards to the vegetation layers' water storage capacity (Maschler et al. 2019). The presented research, embedded in the project RasenTex (ZIM-Kooperationsprojekt ZF4060029AW7, Bundesministerium für Wirtschaft und Energie), aims to improve a vegetation layer system while following the recommendations of the DIN 18035-4:2012-02 standard. This system is intended to be explicitly composed of locally available soil components (Maschler et al. 2019). For improving sportpitches, a nonwoven is actually in research. The nonwoven is expected to enable water from the drainage layer to rise into the root zone of a sport pitch. The present study aims to develop and evaluate a device for the vertical incorporation of a biodegradable nonwoven into the existing vegetation layer of sport pitches. In Germany, 55,072 soccer pitches were in use in the year 2000 (SenBildJug-

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Fam et al. 2002). Wherein 33,139 are classified as large sport pitches, with a size of at least 7,000 m^2 (DFB 2011). High water permeability is necessary in order to discharge heavy rain. On the other hand, a sufficient water supply of the turfgrasses is a major challenge for planning and constructing sports pitches (Huang und Fry 2008, DIN 18035-4: Sportplätze – Teil 4: Rasenflächen 2018). As a consequence, irrigation is necessary. Unfortunately, intensive and frequent irrigation leads to high water consumption. The average irrigation demand of a sports pitch in Germany lies between 75 and 250 mm per year, depending on the region (DFB 2011). Daily water consumption of sport pitches ranges from 2.5 and 7.5 mm (Leinauer et al. 2012). Due to climate change, and especially in regions with low precipitation, an intensive irrigation is necessary. The irrigation season in Germany starts in May and ends in September. High temperatures above 15 degrees allow water demand to rise up to 8 l/day in summer (DIN 2003, DFB 2017). During the winter, usually no irrigation is necessary, however the higher precipitation needs to discharge. Due to more frequent drought periods as a result of climate change, irrigation may be prohibited or restricted (Huang 2008). Because of this, future sport pitches need improved water permeability and simultaneously enhance water supply to the turfs. Turf pitches are standardized within DIN 18035-4 (Lund et al. 2018). The standard recommends a layer-by-layer structure of the pitch. Starting from the upper layer, the proposed structure consists of the rootzone, the drainage and the subgrade. The subgrade consists of the existing subsoil. If the subgrade shows a high water infiltration rate only a rootzone layer with a recommended height of 100 mm is used (Lund et al. 2018). The water infiltration rate of the subgrade must be at least 30 mm/h. In case of an impermeable subgrade, the standard recommends the use of an additional drainage layer. For this purpose, the drainage layer must have a minimum height of 120 mm and a water infiltration rate of more than 180 mm/h. In addition, the unevenness of the drainage layer has to be less than 20 mm on 4 m length. The main layer of standard sport pitches is the so-called rootzone layer. With regard to hydrology, the rootzone layer must have a water infiltration rate of at least 60 mm/h. At the same time, the layer must have a water holding capacity of 30 vol.-%. The unevenness of the layer must be less than 20 mm on 4 m length. The DIN 18035-4 standard allows construction methods to be adapted if the general requirements of the standard are met (Lund et al. 2018). Regarding these requirements, the height of an existing sport pitch is about 220 mm. Therefore, a nonwoven needs to be to incorporated between the drainage layer and the main rooting zone of the sport pitch. It should be placed at a depth of 170 mm to the level of the ground with a high accuracy. The assumption of a depth of 170 mm was made due to the 220 mm height of a standard sport pitch. The nonwoven works like a surface irrigation system (Bin Zainal Abidin et al. 2014). The nonwoven should transport the water from the drainage layer to the root zone due to capillary forces.

To optimize the water balance in existing sport pitches or golf courses, different techniques are used. If the water permeability is low, a slit or a bypass drainage increase infiltration rates without the need for reconstruction (Adams 1986, Cereti et al. 2004, Baird 2005). The operation principle of these machines is very similar to the machine developed in this study. For slitting and incorporating sand or drainage pipes they are constructed with rotating or oscillating blades, that open a trench and then refill the trench with the material, which is to be incorporated (Bentley 2003, McGann 1992, Rogmann 1992). Because of their weight, these machines apply a high surface pressure and often damage the turfgrass (James et al. 2007a). This circumstance may require more maintenance efforts and prolonged usage breaks for turfgrass recovery. The minimization of usage breaks, however, is a central goal of the overall management of sport pitches.

The objective of the study is to construct and evaluate a device for the vertical incorporation of a nonwoven into the vegetation layer of existing sports pitches with the subsequently specified requirements. The incorporating device has to fulfill three tasks. It has to vertically precut the turfgrass, then open a slit vertically, insert the nonwoven, close the slit, and finally to recompact the root zone. The nonwoven has to be installed rectangular to the surface to prevent the nonwoven from being exposed on the top surface.

The working objectives of the present study are the following:

- The accuracy of the working depth must not exceed ± 20 mm.
- Passively driven technology
- The tractive force requirement of the device should be kept low, in order to be able to be attached to low powered towing vehicles.
- The weight of the device has to be minimized, in order to ensure that the three-point linkage can carry it.
- The ground cover of the turf may not be reduced by the incorporation.
- The overall length of the device has to be short in order to keep the turning area as small as possible.
- The surface has to be recompacted in order to restore evenness and connect the nonwoven to the pores of the rootzone and the drainage layer.
- Reduction of turf damage

Materials and Methods

Test area and trial layout

The tests described were conducted between August 23th, 2019 and September 8th, 2019 on turf plots, built according to the DIN 18035-4 standard (DIN 18035-4: 2018). The test site was located at the experimental station Heidfeldhof in Stuttgart, Germany. Three replications (Figure 1), each with a length of 11 m and a width of 4 m, were excavated and a layer-by-layer structure was installed. Each plot consisted of a rootzone layer with a thickness of 130 mm and an underlying drainage layer with a thickness of 120 mm (Figure 2). The sandy soil mixtures of both layers were produced and installed in October, 2018 according to the DIN 18035-4 standard. The root zone mixture had a particle size distribution of 13 % by weight < 0.063 mm, 77 % by weight between 0.063 mm and 2 mm and 10 % by weight between 2 and 6 mm. A standard turf seed mixture type 3.1 (FLL 2019) with a seed rate of 40 g/m^2 was seeded in October 2018. The standard turf seed mixture consists of 50 % perennial ryegrass (*Lolium perenne* L.) and 50 % Kentucky bluegrass (*Poa pratensis* L.) seed. The mowing height of the established turfgrass was 30 mm, using a rotary mower. At the time of installation the unevenness of the rootzone layer was less than 20 mm on 4 m length, measured according to DIN 18035-4. The standard construction design was improved by vertically incorporating a biodegradable nonwoven into the layer structure. This altered construction then consisted of four components: turfgrass, root zone layer, biodegradable nonwoven, and drainage layer. To test the device described in section Material and Methods biodegradable viscose nonwoven bands with a height of 150 mm and a width of 4-5 mm were incorporated on August 26th, 2019. The distance between the parallel tracks was between 200 and 300 mm to avoid severe injury to the turfgrass. Furthermore, each track had a length of 10 m to avoid boundary effects. Eight tracks were applied at each plot (Figure 1). The untreated area of the 4 m wide plots should be used as control, but due to the low water content of 10.2 Vol %. no penetrometer measurements could be done. The installation was carried out at speeds between 1 and 2 km/h, using a John Deere 4049 (John Deere, Illinois, USA) with municipal tires.

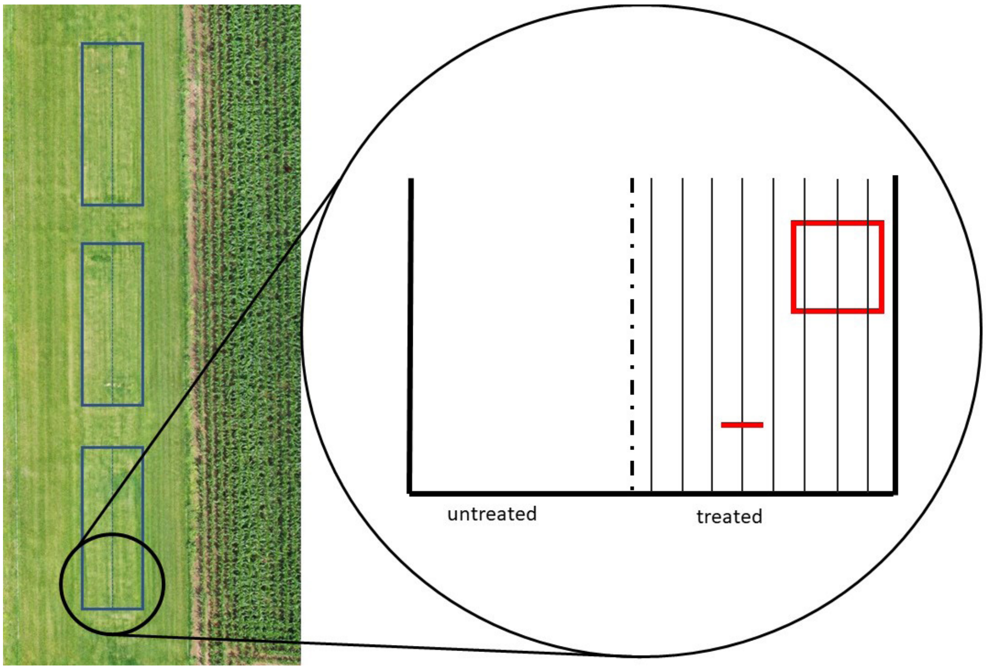

Figure 1: The three measured replications (plots). The detailed view shows the position of the incorporated nonwovens, the position of one random sample with the wooden frame (red square) and one position of the six measurements points with the penetrologger (red line). Ten samples were performed for the visual scoring and four samples were done with the penetrologger in each plot.

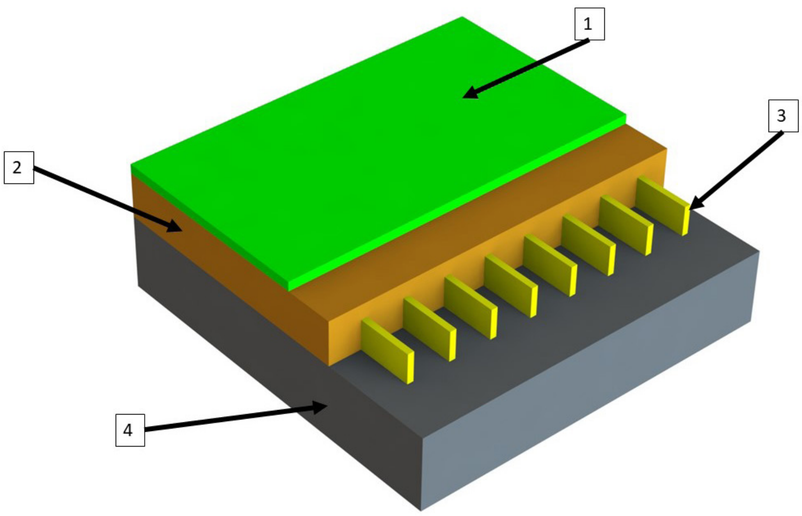

Figure 2: Vegetation layers for sports turfs with incorporated nonwoven: 1) turfgrass, 2) rootzone layer, 3) vertical incorporated nonwoven, 4) drainage layer (© B. Stürmer-Stephan)

Characterization of the nonwovens

The dimensions of the nonwoven bands are important. The nonwoven bands should have a width between 4 and 5 mm and a height of 150 mm. The width should not be less than 4 mm, in order to preserve sufficient tensile strength, and not exceed 6 mm, which would disrupt the vegetation layer. Since the nonwoven needs to connect the drainage layer with the rootzone layer, a height of 150 mm was chosen. The nonwoven for the experiments had a density of 0.175 g/cm^3 (Gebr. Röders AG, Soltau, Germany). Considering the length of an average sport pitch, a strip of nonwoven of about 105 m is to be incorporated during one crossing. Its weight is about 12 kg. Due to the production method, 50 m of nonwoven carrying a weight of 6 kg are stored on one drum. The tensile strength of the nonwoven, which base material is viscose, exceeds 450 N. The capillary structure of the nonwoven may be optimized for transporting water from the drainage layer into the root zone of the turfgrass. Due to the biodegradable properties of the material, disposal costs can be reduced (Maschler et al. 2019). Figure 3 shows an incorporated nonwoven, exposed on one side, connecting the drainage layer with the rootzone layer.

Figure 3: Incorporated nonwoven connecting rootzone layer and drainage layer in one of the test plots.
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Technical description of the device

The device developed as part of the present study consists of six major components (Figure 4). The entire device is pulled and guided by the rear three-point linkage of a towing vehicle. The design of the three-point linkage corresponds to category 1 as described by the ISO 730:2009 standard (ISO 2009). Central component of the device is the frame (A). It has an overall length of 1.8 m and a width of 0.8 m. It is manufactured from square steel tube with the dimension of 100 mm height by 100 mm width. The frame mainly consists of three cross bars linked by side members. The forces occurring at the three-point attachment are dissipated via stiffening struts in the last cross bar. This cross bar carries the roller for the slit recompaction.

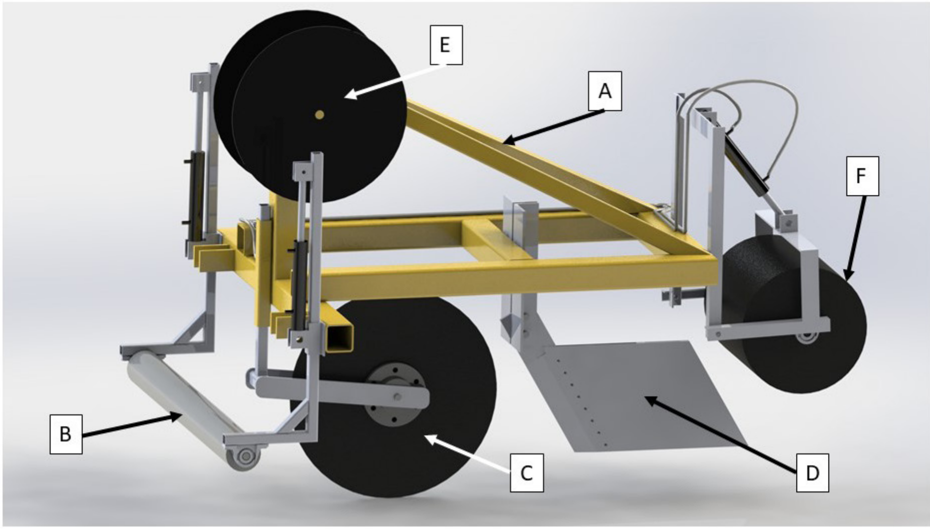

Figure 4: Technical overview of the developed device A) machine frame, B) roller for depth control, C) cutting disk to precut vegetation layer and rootzone, D) box coulter to open the soil and guide textile ribbon rectangular into the created slit, E) reservoir drum for nonwoven textile and F) roller for slit recompaction (© B. Stürmer-Stephan)

The roller for depth control (B) and the cutting disc (C) are attached to the first cross bar in driving direction. The main purpose of the cutting disc is to cut the turfgrass and simultaneously to preform a slit in the vegetation-layer. The cutting disc has a diameter of 58 cm and a width of 5 mm. To overcome the problem of clogging, the use of a passively rotating disc is advantageous. Due to the principle of a pulling cut and the sharp cutting edge, the cutting disc cuts easily through the roots (Nieuwenburg et al. 1992). The working depth of the cutting disc can be adjusted in five height settings by means of a hole grid. The hole grid has uniform spacing of 50 mm to change the working depth in relation to the box coulter. Adjusting the working depth of the cutting disc allows a flexible adaptation to the operating conditions and to the shear strength of the vegetation layer. The cutting disc is driven by the forward movement of the pulling vehicle, there is no active drive to keep the weight of the device low. If the sport pitch is dry and has a high penetration resistance the device can be ballasted with weights.

The box coulter (D) is displayed in Figure 4. It opens the slit, guides and inserts the nonwoven. For that purpose, the box coulter has a width of 15 mm and a cutting angle of 60 degrees. It consists of two metal furrow shaping plates on each side. They have a length of 40 cm and a height of 25 cm. Their function is to keep the slit open and to guide the nonwoven inside the box coulter. The guide plates are mounted with screws to allow simple maintenance or replacement. To avoid a penetration of the substrate from the bottom, the box coulter is closed at the bottom. This arrangement leads to a displacement of soil material in the direction of the sole and the walls of the slit. In the box coulter, a ball bearing is used to guide the nonwoven in height. The nonwoven unrolls by itself from the nonwoven coil (E) with a maximum diameter of 70 cm, depending on the coil dimensions. During the unwinding, the nonwoven is elongated. Due to its specified tensile strength, no active drive of the reservoir drum is necessary. The guidance is facilitated due to the fact that no draping of the nonwoven is expected.

This was assumed due to the high tensile strength of 450 N and the 5 mm width of the nonwoven. In all tests no draping was observed. Different sport pitches based on different construction models may require varying working depths of the device. The condition is that the device can be guided precisely along the ground surface. Therefore, a height guidance is implemented via a continuously height-adjustable guide roller. The working depth is adjusted by a 1.2 m wide guide roller with an outer diameter of 70 mm (B). The working depth can be continuously adjusted via two hydraulic cylinders with a stroke of 20 cm. Since each side of the guide roller is equipped with a hydraulic cylinder a flow divider ensures a synchronized movement of both hydraulic cylinders. Check valves prevent the hydraulic cylinder from pressure loss. The hydraulic cylinders are controlled by the double-acting control units of the towing vehicle. A scale can be used to check the current working depth and for the placement depth of the nonwoven. For recompaction of the rootzone layer, a pressure roller with a width of 45 cm and a diameter of 30 cm is used (F). The pressure roller recompacts the layer surface and closes the slit after the incorporation of the nonwoven (Figure 5). The compacting pressure of the pressure roller can be adjusted by filling the pressure roller with water. Additionally, the compacting pressure can be increased by a hydraulic cylinder, which transfers load from the device to the pressure roller by extending the piston. The hydraulic cylinder is adjusted by the control valves of the towing vehicle. A built-in scale further facilitates the adjustment of the recompaction pressure. A built-in check valve prevents the hydraulic cylinder from pressure loss.

Figure 5. The developed device incorporates a 150 mm height nonwoven in a depth of 170 mm on one of the test plots. The box above the coulter can be used for testing the incorporation of additional sand, but this feature is not investigated within this work. (© B. Stürmer-Stephan)

Determination of the machine working depth

For evaluating the correct working depth of the machine, the level of the ground of the plot and the position of the box coulter had to be determined. First the ground of the plots was determined with a highly accurate robotic landscape surveying instrument (Trimble SPS930) and a monopod with a retroreflecting triple prism (Trimble M900) (Trimble, Sunnyvale, USA). Turf surface points were measured in grids of 0.7 × 0.7 m. A surface was fitted by the 2.5 D quadratic routine, included in the software Cloud-Compare V 2.11 alpha (GPL software). The surface was used for calculating the mesh-cloud distance to the depth of the box coulter. The coulter of the present study, fixed to the rigid frame forms a single unit. So the installation depth of the nonwoven could be measured at the highest point of the machine using the prism. This indicates that the tracked position is 0.6 m above the bottom of the box coulter. The desired installation depth of the nonwoven was 20 mm beneath the surface, measured from the upper edge of the nonwoven. Thus, the desired working depth of the box coulter was 170 mm. This measurement method determines the working depth of the machine. This method thus does not directly determine the depth of the fleece, but at 2-3 samples per plot it was visually checked whether the fleece was installed correctly. Since no twists were detected in the fleece, the working depth of the machine was set equal to the deposit depth of the fleece.

In post processing, the entities of the measured coordinates of the machine were reduced to the size of the plots by using Cloud-Compare. Afterwards the mesh-cloud distance between the position of the box coulter and the fitted surface was calculated and the distance travelled by the device was plotted for the central 10 m of each plot. The root mean square for the regression for all eight profiles of each plot was calculated. The average for each plot is presented in the results. The root mean square was used because the plots had a slope and otherwise the mean of the measurements would not be accurate. Furthermore, the data of all eight profiles were interpolated with SigmaPlot 14.03.192 (Systat Software GmbH, Erkrath, Germany) to the same lateral distance of 50 mm between data points. Afterwards the mean differences to 170 mm (nonwoven with 150 mm height and 20 mm installation depth) for each data point of the eight interpolated profiles were calculated. Additionally, the standard deviation of this interpolated profiles were calculated for each of the data points.

Determination of the recompaction and incorporation

For assessing the recompaction, the penetration resistance was measured transverse to the installation direction of the nonwoven, that is working direction of the device. This means the penetration resistance was measured along a cross-section of the slit surrounding soil. Measurements were done using an electronic penetrometer of the type Penetrologger (Ejkelkamp Soil & Water, Giesbeeck, Netherlands). The penetrometer measurements were taken up to a depth of 200 mm. Three measurements were carried out on both sides of the nonwoven in intervals of 20 mm. They were taken transverse to the installation direction, starting at each side of the nonwoven. Four repeated measures were performed for each plot, each in a different position within the plot (Figure 2). The positions were located in zones where visually no side-effects could be observed. For each plot a contour map was created, based on the arithmetic means of the four repeated measures. The contour map routine of Sigma Plot was used. For the assessment of the results, the soil moisture was measured with a time domain reflectometry testing probe (IMKO Micromodultechnik, Ettlingen, Germany). The average soil moisture content in the presented study was 10.2 Vol %. Due to the low water content of the rootzone layer, no control measurements could be taken at the remaining part of the plots because the value of penetration resistance was out of the measuring range of the penetrometer. This means the penetrometer could not penetrate the sandy root zone layer at the remaining part of the plots, where no nonwoven was incorporated.

Determination of the turf damage

Minimizing the damage of the turf was important when developing the device of the present study. Visual scoring of the ground cover in percent was used for evaluating the impact of the machinery on the turf, using a wooden frame according to DIN 12231 (DIN 2003) of one square meter size (Figure 6). Defines a square pattern accordingly 100 x100 mm. The visual scoring was performed in increments of 10 %, from 0 to 100 % ground cover. Visual scoring took place three days before incorporation of the nonwoven, shortly after incorporation of the nonwoven, and eight weeks afterwards. Results of visual scoring before incorporation were used as untreated for the trials. Ten replicate measures were taken for each plot (Figure 2). Descriptive statistic was done using Rstudio Version 1.1.463, Cloud Compare V 2.11 alpha and SigmaPlot 14.03.192. Arithmetic mean and standard deviation were calculated.

Figure 6: Wooden frame according to DIN 12231 (DIN 2003) on a part of the treated turf; the closed slits can be recognized (© B. Stürmer-Stephan)

Results and Discussion

Machine working depth

In order to evaluate the variation of the working depth, the root mean square (RMS) of the eight measured profiles were calculated. Table 1 shows that the average RMS values for the plots were between 6.0 mm and 8.3 mm. The highest RMS was detected in plot 3, which may have been due to an uneven surface before the incorporation process (Table 1). The standard deviation ranging between 1.1 and 2.0 mm was considered to be acceptable because the resolution of the landscape surveying instrument is ± 1 mm. All tested plots had a RMS lower than 10 mm (Table 1), which met the desired accuracy. These results demonstrate that the device operates within the desired parameters.

Table 1: Average root mean square of the working depth in mm for each of the tested plot and the standard deviation of the root mean square (RMS) of the plots in mm

Plot	Average root mean square (RMS) in mm	Standard deviation of RMS in mm
Plot 1	6.0	1.1
Plot 2	7.3	2.0
Plot 3	8.3	1.6

The red line in Figure 6 shows the mean difference to the desired working depth of 170 mm for each plot. For the eight profiles of the plot the standard deviation of this difference was calculated and presented as error bars in the same figure. The beginning and the end of the plots is just showed to determine the pull-in and pull-out behavior of the device (Figure 6). The results indicate that the standard deviation of the working depth of the tracks of plot 1 (a) only differ less than 1 mm. This conclusion is supported by the low standard deviations between the repeated measures of this plot. Mainly, there is a higher standard deviation at the first 2.5 m and at the last 2 m of the plot, due to boundary effects. A higher mean error above 20 mm occurs in the plot 2 (b) at the end of the plot, between 8 and 10 m distance from the starting point (Figure 7). The mean errors of the intended working depth in each plot are lower than 20 mm, but by a positive tendency (Figure 7). These results indicate that the accuracy of the incorporation of the nonwoven is high enough, according to the conditions of the plot. According to the standard deviation a range of values lower than 7 mm is presented (Figure 7).

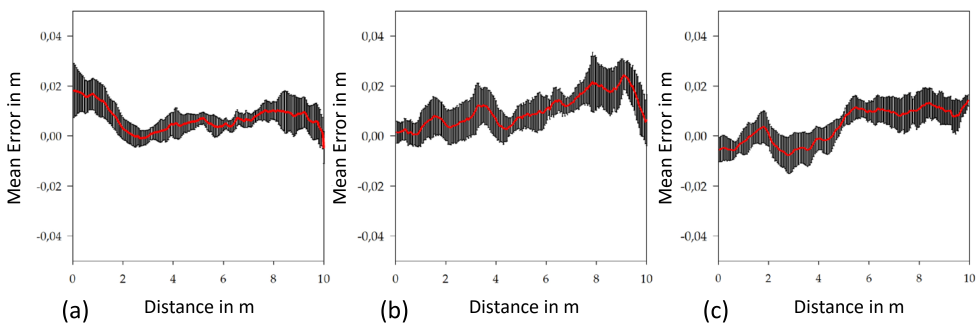

Figure 7: Mean errors to 170 mm working depth of the eight measured tracks on plot 1 (a), plot 2 (b) and plot 3 (c), error bars show standard deviation

The measured working depth differ significantly from the expected working depth of 170 mm during the first and the last 2 m of the plot. This may occur because the device needs more driving way and speed to penetrate the root zone during the first meters. At the end of the plot the device was pushed to the top, perhaps because the towing vehicle slowed down at the end of the plot. These observations may explain the low accuracy of the working depth at the end and the beginning of the plot and the higher accuracy in the middle part of the plot. However, no nonwoven was visually observed above the surface of the plots. A soccer shoe has cleats with a length of about 10-15 mm, so that the nonwovens could not affect players (Park et al. 2005). It is essential that the nonwoven is located more than 20 mm deep in the drainage layer in order to meet the demands of the developed turf system. The results presenting the working depth, indicate that the developed machine is able to meet these requirements. However, the measurements showed that in some areas of the plot the working depth shifts towards the surface of the pitch. For the further development of the device this result should be particularly considered. A solution could be a heavier device or a ballasting of the device. In future studies, the plots should be longer to guarantee a constant speed along the trial. A higher rotational speed of the cutting disc would result in a better working quality (Tice and Hendrick 1992). However, it must be noted that the forces acting upwards become greater (Tice and Hendrick 1992).

Incorporation and Recompaction

In order to evaluate the recompaction of the rootzone layer by the pressure roller, the penetration resistance was measured. Figure 8 shows the distribution of the penetration resistance over the penetration depth, with the position of the nonwoven being depicted in the center. In the upper part of the rootzone, the penetration resistance increases by depth. It is evident that the low values up to a depth of 20 mm result from the high content of organic matter consisting of roots and thatch. The values of penetration resistance next to the nonwoven are lower than the values at a larger distance to the incorporated nonwoven. Down to a penetration depth of 40 mm, the penetration resistance is below 0.5 MPa. At the lower edge of the nonwoven, at a depth of 160 and 180 mm, the penetration resistance is lower than 1.5 MPa. Figure 8 shows that the lateral distribution of the penetration resistance is uniform. Only the coulter sole shows lower values compared to the values at a distance of 60 mm to the nonwoven. The reason could be the sandy root zone mix, which is lateral displaced by the box coulter, in conjunction with the very dry soil conditions. After the incorporation of the nonwoven the root zone mix may have been fallen in the newly- formed hollow space. Normally, the penetration resistance of a turf pitch, which was built in accordance to the standards, is about 1 to 4 MPa depending on the soil water content and the construction method (Morhard 2004, Holzinger 2011). Results indicate, that the pressure roller leads to similar values, except of the direct surrounding of the nonwoven. In this area the recompaction failed, most probably because of the low water content of 10.2 Vol%. A technical solution to this issue could be an increase of the vertical load on the pressure roller or the use of another type of pressure roller, like a v-shaped pressure roller (Hinrichsen and Kushwaha 1989). On the other hand, the loosened substrate around the nonwoven increases the soil gas exchange, which is presumed to result in a better rooting of the vegetation (Bunnell et al. 2002). Therefore, in further studies the functionality of the nonwoven has to be investigated with regard to these aspects, with focus on the influence of the low recompaction on the playability of the sport surface.

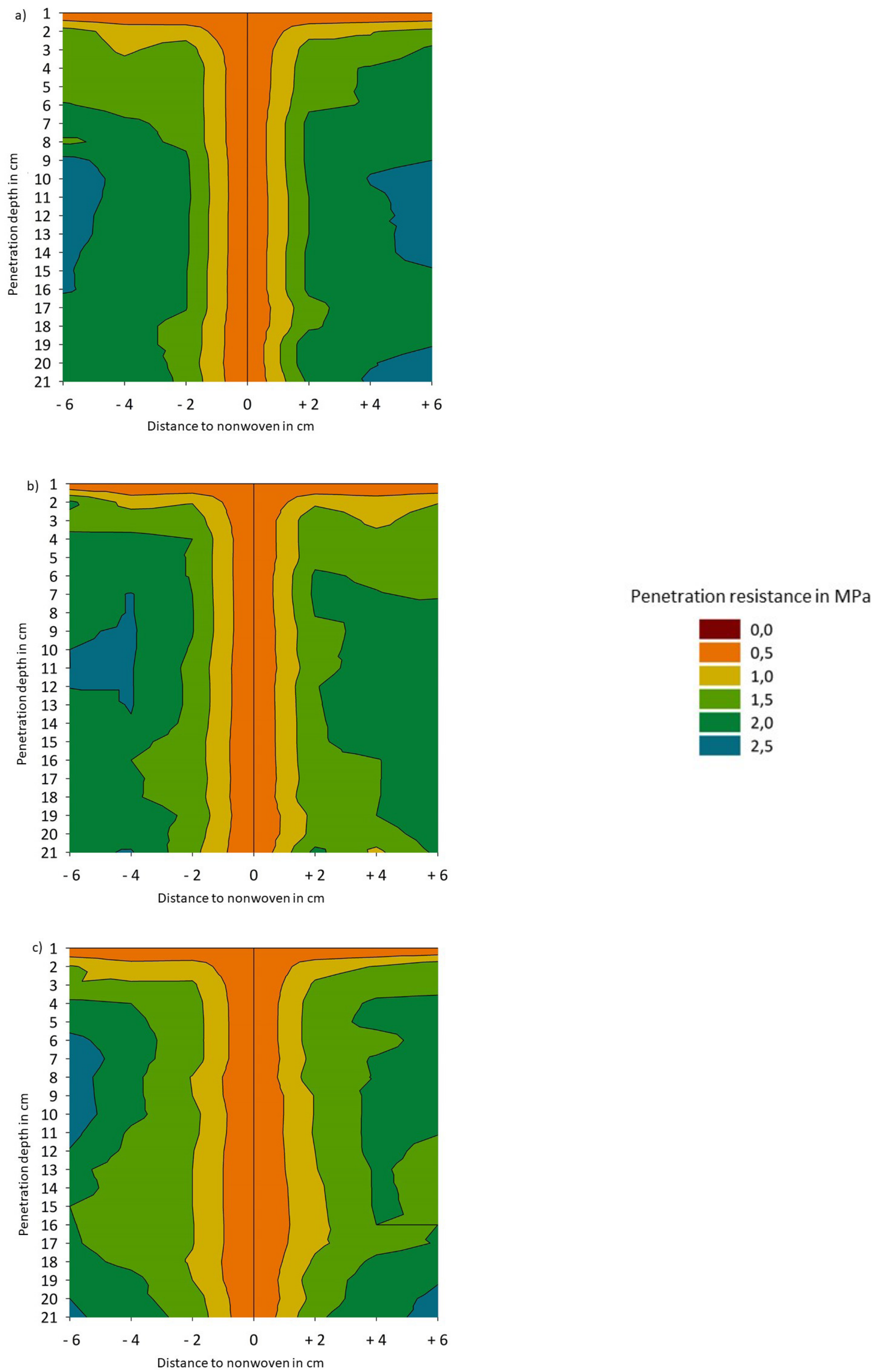

Figure 8: Penetration resistance (MPa) - cross-section of plot 1 (a), plot 2 (b) and plot 3 (c), close to the nonwoven, after incorporation; the nonwoven position is schematically shown in the center of each figure by a grey rectangle

Evaluation of the turf damage

The visual scoring of the turf damage depicted a lower ground cover after the incorporation of the nonwoven. The damage that results from the cutting disc and the pressure roller is evident but marginal. The slots of the box coulter reduce the ground cover by 10 to 15 % (Figure 9). However, the slots are closed and compared to James et al. (James et al. 2007c) no grass die-back was observed. Eight weeks after the treatment the ground cover did not differ from the determined status quo. The DIN 18035-4 standard requires more than 95 % coverage for acceptance of a new built sport pitch (DIN 2018). On the other hand, the German Football League requires a ground cover of more than 60% for a game at national league level (DFL 2018). Regarding the ground cover, the results ensured a possible playability of the sports field even immediately after the treatment according to the German Football League (Figure 9). Because the original ground cover could be restored after eight weeks the device meets the desired requirements. The trials also showed, that the box coulter and the cutting disc must be perfectly aligned to avoid turf damage.

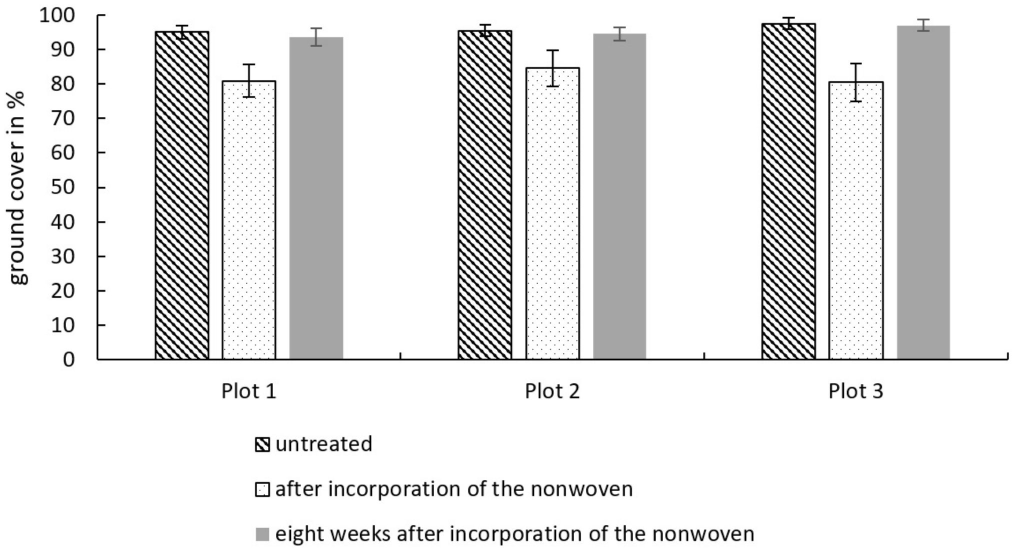

Figure 9: Mean ground cover (%) of plot 1, plot 2 and plot 3, untreated (three days before incorporation), after incorporation and eight weeks after incorporation of the nonwoven; error bars shows the standard deviation

To compare the results with the current state of research, the device can be compared with a mole plough. Even though not widely spread, mole ploughing for the drainage of sport pitches represents a similar interference with the turfgrass. For application of this technique, it is also important that the damage of the turf remains as low as possible. James et al. (2007c) described that in case of mole-drains, reducing the slit-spacing reduces the time between the treatment and the restoring of playability. Therefore, the distance of the slits in the presented trials is only 250–300 mm. The mole plough had a plough foot diameter of 50 mm and a working depth of 40 cm (James et al. 2007b). The mentioned authors recommend the width of the mole-plough leg to be smaller than 25 mm. The box coulter width of 15 mm is even below this value. The results of the visual scoring showed that the width of the box coulter did not significantly damage the turf.

Conclusions

This study describes the results of an evaluation of a newly developed device. The function of this device is to incorporate nonwovens into existing sport pitches. The results showed that the accuracy of the device's working depth meets the requirements. A lower accuracy was only observed at the beginning and the end of each plot. Since the plots were a little lower than the headland, the guide roller lifted the machine out of the ground. This, however, should not occur on sport pitches which normally only have a gradient of 0.5 % to 1 % (DIN 2018). At the time of the trials, the plots had a very low water content of 10.2 Vol.%. Visual observation showed that the pressure roller restores the surface as desired. However, the penetration resistance indicates that the recompaction, especially under the lower edge of the vertical incorporated nonwoven, needs to be increased. This will avoid unevenness due to sinking of the surface. Under these test conditions no sinking was observed. The area with low penetration resistance showed an increase of air filled pores. Aeration is regularly performed on sports pitches to increase water permeability and supply the root zone with air (Aldous et al. 2001). Further research is needed to investigate this loosening in relation to the negative effects on the surface hardness. The turf was only damaged slightly, indicating that the chosen method of incorporation is appropriate. The cutting disc works properly since no clogging was observed at the box coulter. Clogging is the main reason for turf damage when regarding mole ploughing or the incorporation of sand slits (James et al. 2007a).

In addition to the presented study, more research is needed to investigate the benefits of nonwovens with regards to water use, turf cover, and wear. The evaluation of benefits of the nonwoven are still in research and will be published in the future. The presented pretests showed that the device mostly fulfills the requirements. In future research, the device needs to be tested under different soil conditions or working depths. Even applications to reduce soil erosion in native soils are imaginable. In this case the device would need to be reinforced and supplemented by an overload protection, due to the higher penetration resistance of native soils.

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Authors

M.Sc. Stephan Bastian Stürmer and **Dr. Jörg Morhard** are members of the scientific staff, **Prof. Dr. sc. agr. Hans Griepentrog** is director at the University of Hohenheim, Institute of Agricultural Engineering, Technology in Crop Production, Garbenstr. 9, 70599 Stuttgart, Germany. E-Mail: b.stuermer-stephan@uni-hohenheim.de

Notes

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